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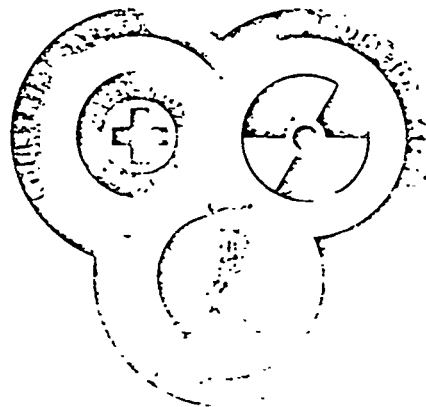
OAK RIDGE NATIONAL LABORATORY

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Congenital Malformation and Fetal Mortality Trends in Counties Surrounding Oak Ridge

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Contract No. W-7405-eng-26

CONGENITAL MALFORMATION AND FETAL MORTALITY TRENDS IN COUNTIES SURROUNDING OAK RIDGE

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Date Published – December 1979

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ACKNOWLEDGMENTS

ABSTRACT

Stillbirth and congenital malformation death data have been evaluated for counties surrounding the Oak Ridge nuclear facilities. The observed values were compared with expected values, based on state of Tennessee and East Tennessee rates, for three time periods: prior to the existence of the nuclear facilities; the early years of operation; and the later years of operation. Oak Ridge, which is the closest city to the nuclear facilities, had significantly fewer stillbirths and no difference in congenital malformations as compared with the state or East Tennessee. No time trend was observed in the 8-county data which could be associated with the higher levels of radioactive releases during the 1944-1957 period followed by a period of lesser releases in the 1958-1971 period. However, a clustering of stillbirths was found for the last time period. In the study, no significant relationship was found between the occurrence of stillbirths and congenital malformation deaths.

INTRODUCTION

Rationale for Study

Since the beginning of the "atomic era," there has been speculation concerning the health of the residents surrounding nuclear facilities. In particular, increased rates of cancer, congenital malformations, and stillbirths are often mentioned as sensitive indicators of the effects from radiation exposure. This report analyzes the incidence of deaths attributable to congenital malformations and fetal deaths for counties surrounding the Oak Ridge nuclear facilities.

Oak Ridge is the site of one of the earliest established nuclear facilities; therefore, the population surrounding this facility has been exposed to manmade radioactive effluents for as long a period as any other population near nuclear activities. In addition, the Oak Ridge facilities have operated in a war-time and a peace-time capacity. During the first period, the most pressing need was to produce weapons-grade material to end World War II, and up until the mid 1950s, similar work continued during the Cold War and arms build-up. As a consequence of the urgency of this work, less than presently accepted attention was paid to environmental releases.

Since the mid 1950s comparatively minor airborne releases have occurred, in contrast to the earlier time period. The historical situation, therefore, affords the possibility of studying a population: (1) prior to the existence of a nuclear facility, (2) during its highest environmental release period, and (3) during a lower release period.

In the present study, two indicators are used which are thought to be among the more directly sensitive to changing levels of biological insult: fetal death and congenital malformations, which in this study are identified by deaths due to congenital malformations. Further, the present study is primarily a descriptive "ecological study" and is not appropriate for substantive testing of hypotheses; its primary utility is to provide a basis for hypothesis generation. Previously, four health-related studies of Oak Ridge populations have been reported, and these are summarized below.

Prior Oak Ridge Investigations

The first paper to analyze the health of the Oak Ridge residents
was by Moshman and Holland.[1] They studied the occurrence of cancer in
Oak Ridge residents for the single year 1949 using cancer morbidity
statistics. Cancer was defined to include all malignant neoplasms,
including leukemias and lymphomas; this tended to maximize the incidence.
Their study showed the age-standardized incidence of cancer among the
Oak Ridge resident population to be 123 cases annually per 100,000. This
was significantly lower than the accepted national annual rate at that
time of 230 per 100,000. The low cancer rate was found to be in
harmony with the low death rate in Oak Ridge from most diseases. Among
white males, a significantly higher proportion of cancer of the respira-
tory system was found than might be expected by chance from the 1938
national averages; however, an explanation on the basis of a long
established upward trend in cancer of the respiratory system, due to
smoking, among males was suggested.[1]

Larson et al.[2] conducted the second study of Oak Ridge employees.
They studied the total number of deaths experienced by employees in
the three Oak Ridge nuclear facilities over a 16-year period, 1950
through 1965, and compared the total number of Oak Ridge deaths to the
deaths which would be expected by applying the 1962 U.S. Bureau of
Vital Statistics mortality rates to the employee population over this
period of time. Based on 207,204 man-years of employment, 692 deaths
occurred compared to the 992 expected. Thus, the results showed that
the workers were less likely to die at any given age than the national
population, which contains various segments of people who have low indices
of health. It was speculated[2] that this phenomenon was due in part to the
"healthy worker" effect, in that only the healthy population is included
in the work force.

The third Oak Ridge study was conducted by Scott et al.[3] In this
study, the employee population was divided into two groups, uranium
workers and nonuranium workers, and the time period of 1951 through 1969
was covered. Uranium workers considered were those who regularly worked
in uranium processing areas and submitted routine samples for uranium

analysis. This group consisted of 4553 employees with a total of about 14,230 man-years of association with uranium processing. The "non-uranium" group was made up of a broad spectrum of employee classifications, such as technicians, administrators, professionals, secretaries, and craftsmen, and this group had 9821 employees for a total of 39,240 man-years. A direct comparison between uranium and nonuranium workers was not appropriate, because the groups differed in proportionality by sex, age, and race. Instead, a direct comparison was made of the ratio of the number of actual deaths to an expected number of deaths for each group, which was calculated by using the 1962 U.S. Bureau of Vital Statistics mortality rates. The ratio of actual to expected deaths for the uranium workers was 0.59; the ratio of actual to expected deaths for the nonuranium workers was 0.76.

The final Oak Ridge study, prior to the present investigation, was conducted by Patrick.[4] He studied stillbirths, infant deaths, congenital malformation deaths, and cancer deaths for 1929 through 1971 in Anderson and Roane counties and the city of Oak Ridge. He plotted total death trends for the above-mentioned causes and found no evidence which would suggest that the Oak Ridge area has been or is becoming a relatively hazardous locale. He also performed chi-square tests for various cancers in Anderson and Roane counties for 1950-1969 and found that the number of actual deaths when compared to national averages was statistically no different from the number expected for males and females of both white and nonwhite populations.

METHODS OF STUDY

The data used in this study were obtained from magnetic tapes and annual bulletins on vital statistics provided by the Tennessee Department of Public Health. The analysis was restricted to the white population as stillbirth and congenital effects due to radiation exposures should show up equally among racial groups, and the nonwhite population is subject to much larger reporting errors, especially prior to the 1950s than is the white population. Stillbirth and congenital malformation data were obtained from 1930 through 1971. To analyze the trend of deaths before and after the start-up of operations at Oak Ridge, the time period was divided into three equal segments: 1930 to 1943, 1944 to 1957, and 1958 to 1971 for the reasons specified in the Introduction. For each cause of death, eight counties were analyzed in relation to the state and to East Tennessee to obtain expected deaths. The counties examined for increased levels of health effects were Anderson and its contiguous counties: Campbell, Knox, Loudon, Morgan, Roane, Scott, and Union. Anderson and Roane counties are often cited in the study as the nuclear facilities are located in these two counties. The counties shown in Fig. 1 for the eastern third of Tennessee minus the above-mentioned eight counties were summed together to form a control for the eastern part of the state. The only city analyzed was Oak Ridge.

Stillbirth trends in this report are referred to in terms of rates. The methodology of calculation — stillbirths per 1000 live births — is, however, often referred to as ratio. Conventional rates, that is, number of stillbirths divided by the sum of live births and stillbirths can be calculated from Appendix A.

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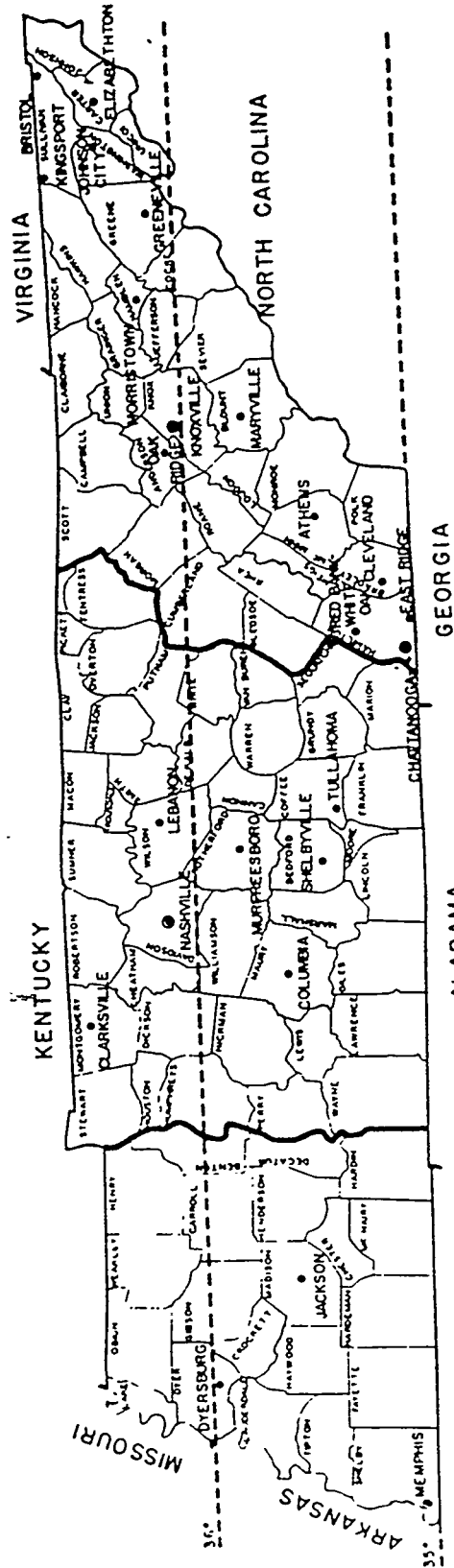
Fig. 1. Map of Tennessee. (Source: Tennessee Vital Statistics Bulletin, 1960.)

• CITIES OF 10,000 TO 35,000 POPULATION IN 1960

● CITIES OF 100,000 OR MORE POPULATION IN 1960

RESULTS

Stillbirths

The stillbirth data are presented in their entirety in Appendix A.
All of the county and city data are compared to expected values, which
were computed first using state rates, and then using East Tennessee
rates. The data for the three time periods are given in Tables 1 through
3, with the chi-square value for each particular interval. The results
are graphically presented for the eight-county area in Fig. 2.

Table 1. Stillbirth data for 1930 to 1943

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	243	236	0.21	246	0.03
Campbell	292	310	1.05	323	2.98
Knox	1229	1280	2.03	1333	8.11[†]
Loudon	238	190	12.1[*]	197	8.53[*]
Morgan	128	133	0.19	139	0.87
Roane	227	262	4.68[†]	272	7.44[†]
Scott	124	115	0.70	120	0.13
Union	74	77	0.12	80	0.20

[*]Observed significantly greater than expected.

[†]Observed significantly less than expected.

$\chi^2_{df=1, \alpha=0.05}$ (two-tail) = 3.84.

From the data presented (Appendix A), it can be noted that, for the
state as a whole, a continuous decrease is evident in the stillbirth
rate over the period 1930-1971. This is indicative of the better health
care that has become available to expectant mothers over the years. The
stillbirth rate over time for various groups is shown in Fig. 3. The
observed stillbirths in Anderson County were also compared to the expected
values predicted from the combined rates in Knox and Blount counties.
These three counties are listed in the same state economic area (SEA),

Table 2. Stillbirth data for 1944 to 1957

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	352	401	6.00[†]	441	18.0[†]
Campbell	297	214	32.2[*]	235	16.4[*]
Knox	1237	1158	5.39[*]	1273	1.02
Loudon	142	135	0.36	148	0.24
Morgan	94	87	0.56	95	0.01
Roane	246	208	6.94[*]	229	1.26
Scott	127	110	2.63	121	0.30
Union	46	42	0.38	46	0.00
City					
Oak Ridge (1949-1957)	76	133	24.4[†]	147	34.3[†]

[*]Observed significantly greater than expected.

[†]Observed significantly less than expected.

$\chi^2_{df=1,\ \alpha=0.05}$ (two-tail) = 3.84.

Table 3. Stillbirth data for 1958 to 1971

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	209	219	0.46	237	3.31
Campbell	144	112	9.14[*]	120	4.80[*]
Knox	931	870	4.28[*]	939	0.07
Loudon	107	84	6.30[*]	90	3.21
Morgan	57	50	0.98	54	0.17
Roane	179	140	10.9[*]	151	5.19[*]
Scott	93	70	7.56[*]	75	4.32[*]
Union	44	32	4.50[*]	35	2.31
City					
Oak Ridge	65	91	7.43[†]	98	11.1[†]

[*]Observed significantly greater than expected.

[†]Observed significantly less than expected.

$\chi^2_{df=1,\ \alpha=0.05}$ (two-tail) = 3.84.

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CHI-SQUARED COMPARISONS USING
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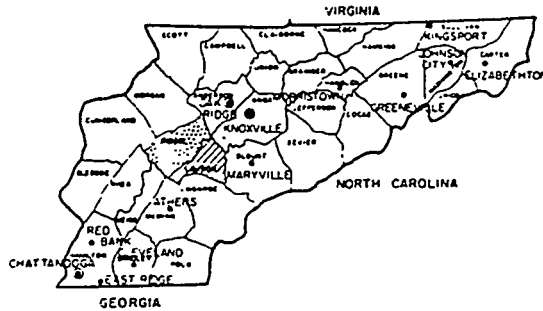
CHI-SQUARED COMPARISONS USING
EAST-TENNESSEE EXPECTED RATES
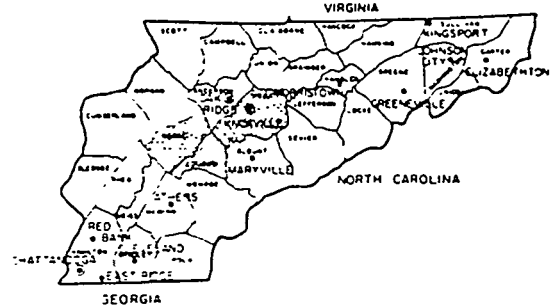
1930—1943

1930—1943
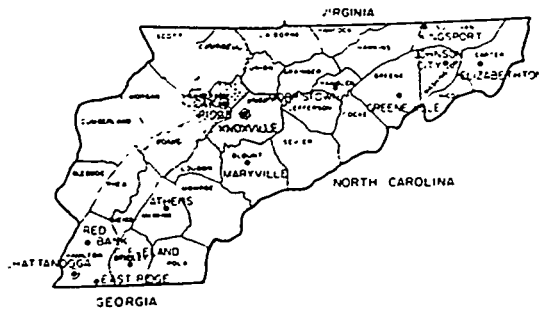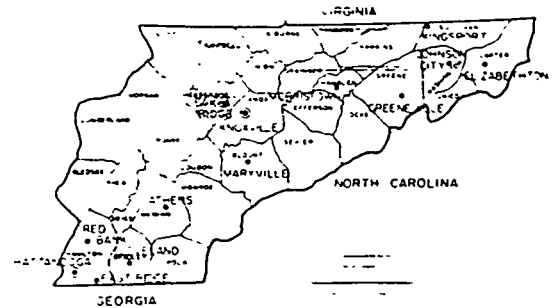
1944—1957

1944—1957
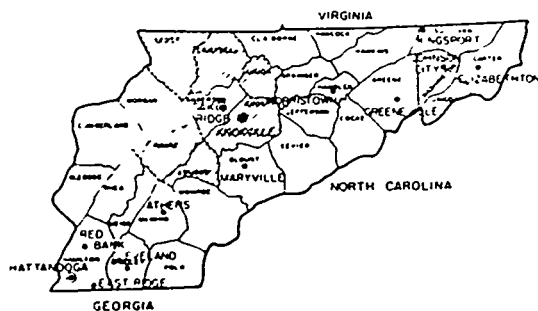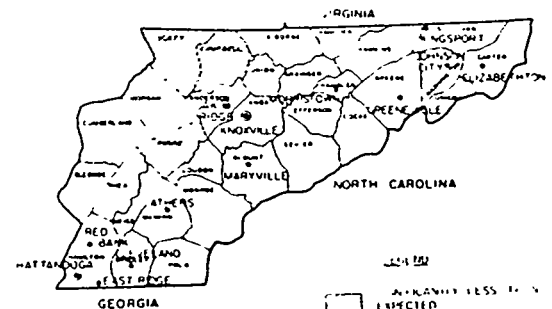
1958—1971

1958—1971

Fig. 2. Spatial orientation of stillbirth data.
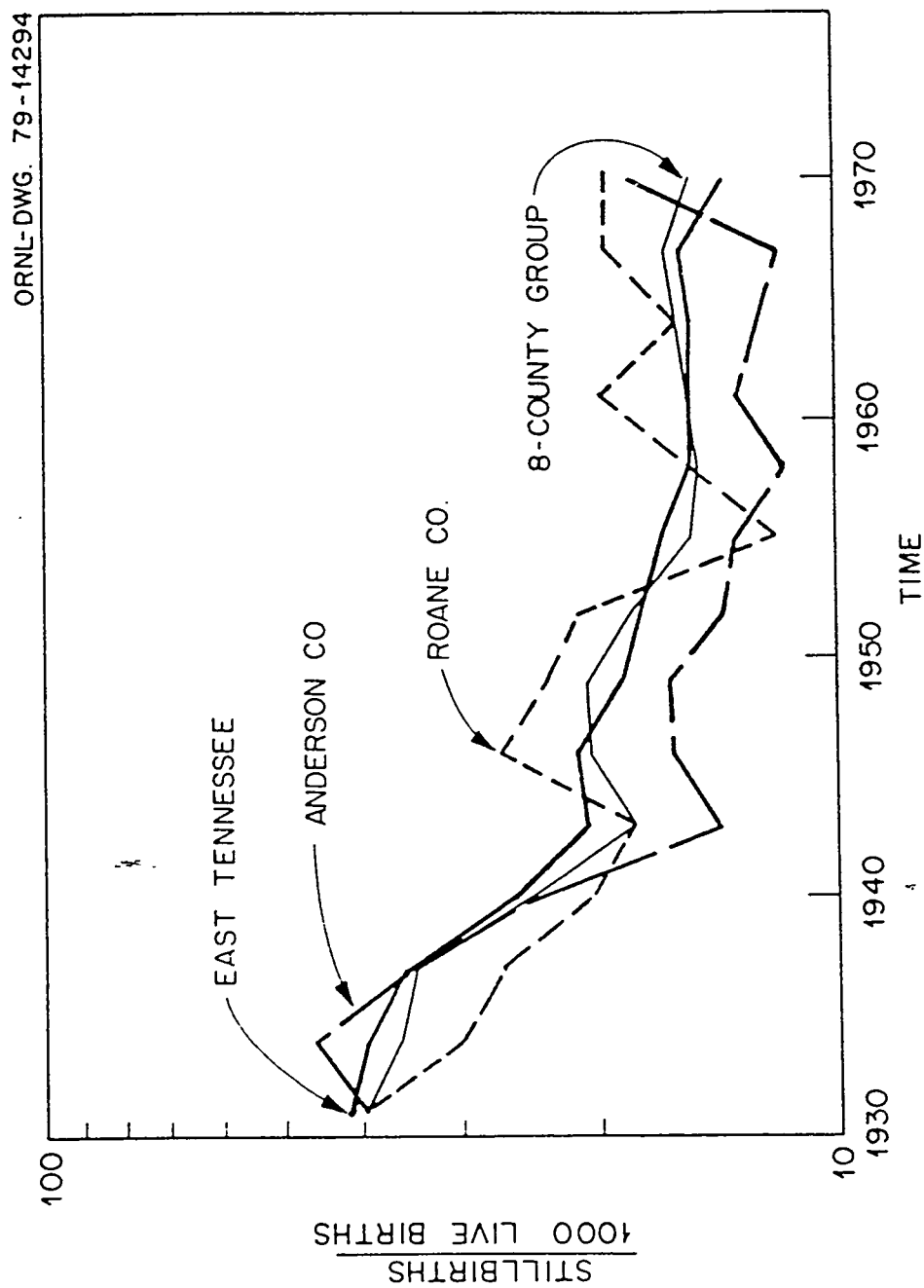
Fig. 3. Stillbirth rate vs time.

indicating some degree of similarity in the socioeconomic mix of people. When the expected for Anderson County is calculated using the combined rates from Knox and Blount counties, Anderson has more stillbirths than expected for 1930-1943, significantly less than expected for 1944-1957, and less than expected for 1958-1971.

Further, the city of Oak Ridge has had a significantly lower number of stillbirths than expected ever since the city first recorded vital statistics in 1949. Finally, it can be seen that, for the time period 1958-1971, more of the eight contiguous counties were significantly worse than the eastern part of the state or the state as a whole than for the other time periods. However, as seen in Fig. 4, even though the eight counties are skewed toward the higher end of the distribution plot, all of the counties are within the normal distribution with none greater than the 95th percentile.

Congenital Malformations

The congenital malformation data, like the stillbirth data, are grouped into aggregated time periods. For these time periods, observed values for Anderson County and the surrounding counties are compared with expected values, using the state and East Tennessee as controls.

Based on year of death

The data are presented in Tables 4 and 5, with Appendix B showing the data in its entirety. Spatial orientation of the data is shown in Fig. 5. The data is only from 1949, as it was recorded separately from other infant deaths from that date in the vital statistics bulletins, and the data tapes containing death records are only available back to 1949. The overall trend, for the state as a whole, has been downward for the congenital malformation rate, although it does not display a temporal relationship as strongly as the stillbirth data. The congenital malformation death rate over time is shown in Fig. 6. The only county that was shown to be significantly greater than expected for both time intervals is Campbell County when compared to East Tennessee. Anderson County also had significantly more congenital deaths based on East Tennessee rates in

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TENNESSEE COUNTIES

STILLBIRTH RATE 1958 - 1971
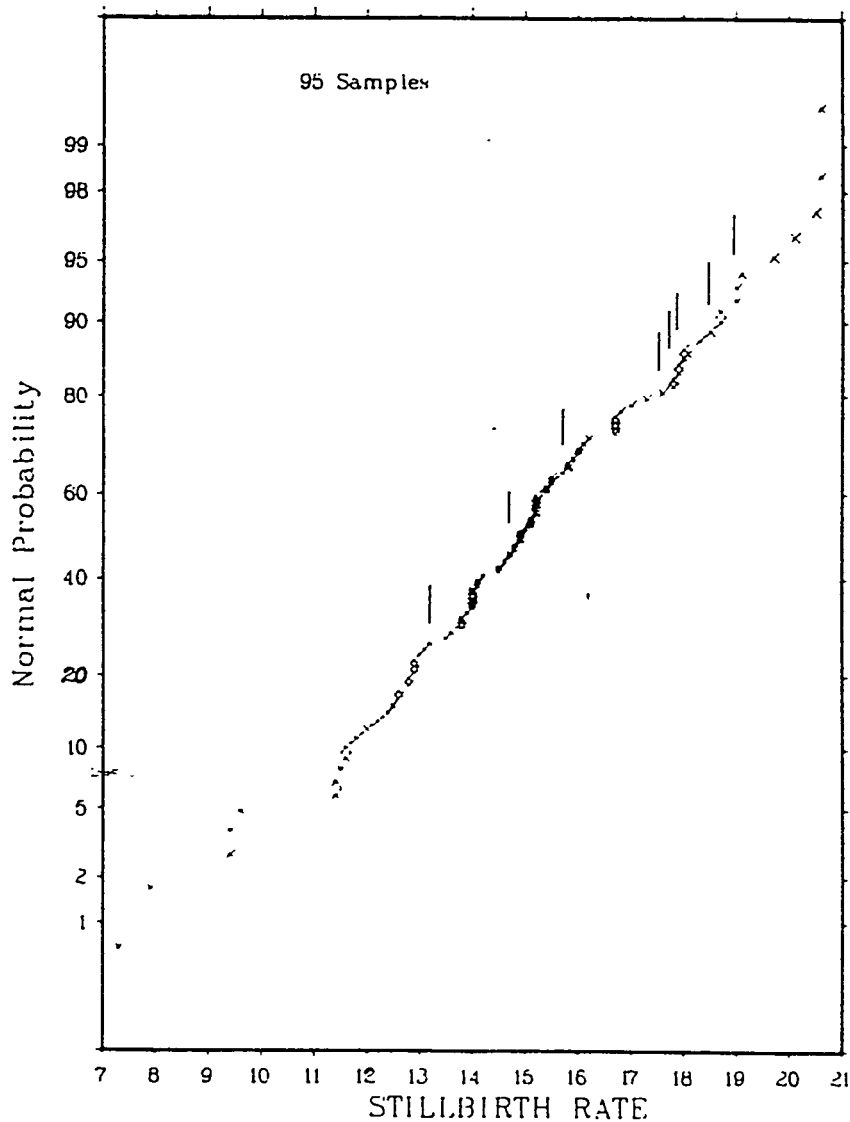
Fig. 4. Distribution of stillbirth data, 1958 to 1971. (The counties under study are indicated by vertical markers.)

Table 4. Congenital malformation data for 1949 to 1957

(based on year of death)

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	72	71	0.01	69	0.13
Campbell	64	43	10.26*	42	11.52*
Knox	254	265	0.46	257	0.04
Loudon	29	33	0.48	32	0.28
Morgan	14	19	1.32	19	1.32
Roane	47	39	1.64	38	2.13
Scott	22	22	0.00	21	0.05
Union	7	11	1.45	10	0.90
City					
Oak Ridge	32	36	0.44	35	0.26

*Observed significantly greater than expected.

$\chi^2_{df=1,\ \alpha=0.05}$ (two-tail) = 3.84.

Table 5. Congenital malformation data for 1958 to 1971

(based on year of death)

| County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	116	101	2.23	96	4.17*
Campbell	61	49	2.94	47	4.17*
Knox	348	411	9.66†	394	5.37†
Loudon	37	41	0.39	39	0.10
Morgan	25	24	0.04	23	0.17
Roane	46	65	5.55†	62	4.13†
Scott	34	27	1.81	26	2.46
Union	11	15	1.07	15	1.07
City					
Oak Ridge	47	48	0.02	46	0.02

*Observed significantly greater than expected.

‾Observed significantly less than expected.

$\chi^2_{df=1,\ \alpha=0.05}$ (two-tail) = 3.84.

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CHI-SQUARED COMPARISONS USING
EAST-TENNESSEE EXPECTED RATES
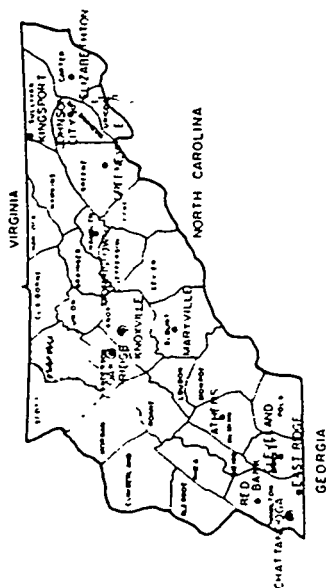
1949-1957

1958-1971

CHI-SQUARED COMPARISONS USING
STATE EXPECTED RATES

1949-1957

1958-1971

LEGEND

SIGNIFICANTLY LESS THAN EXPECTED

SIGNIFICANTLY GREATER THAN EXPECTED
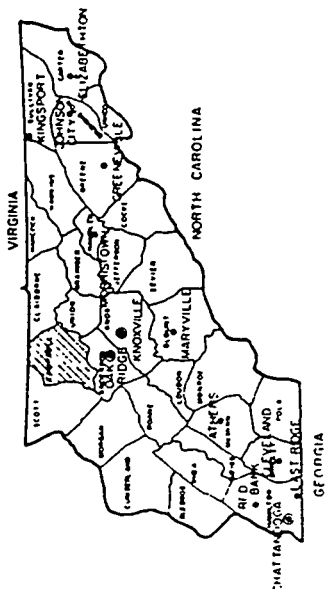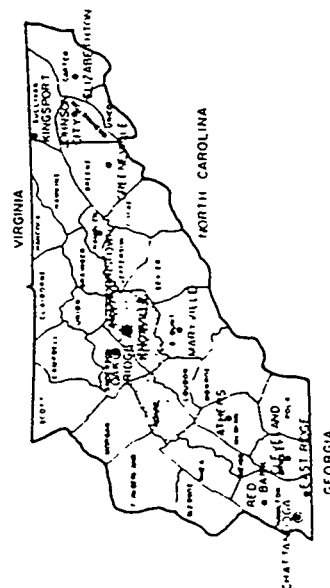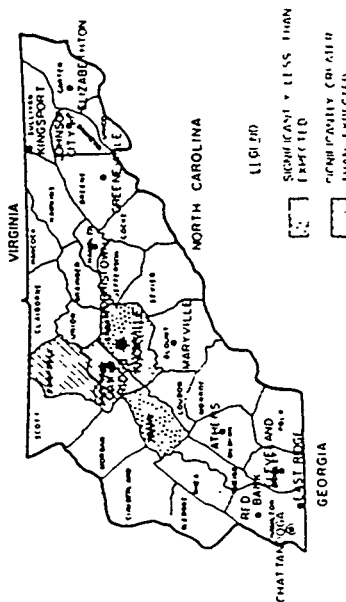
Fig. 5. Spatial orientation of congenital malformation data (year-of-death technique).
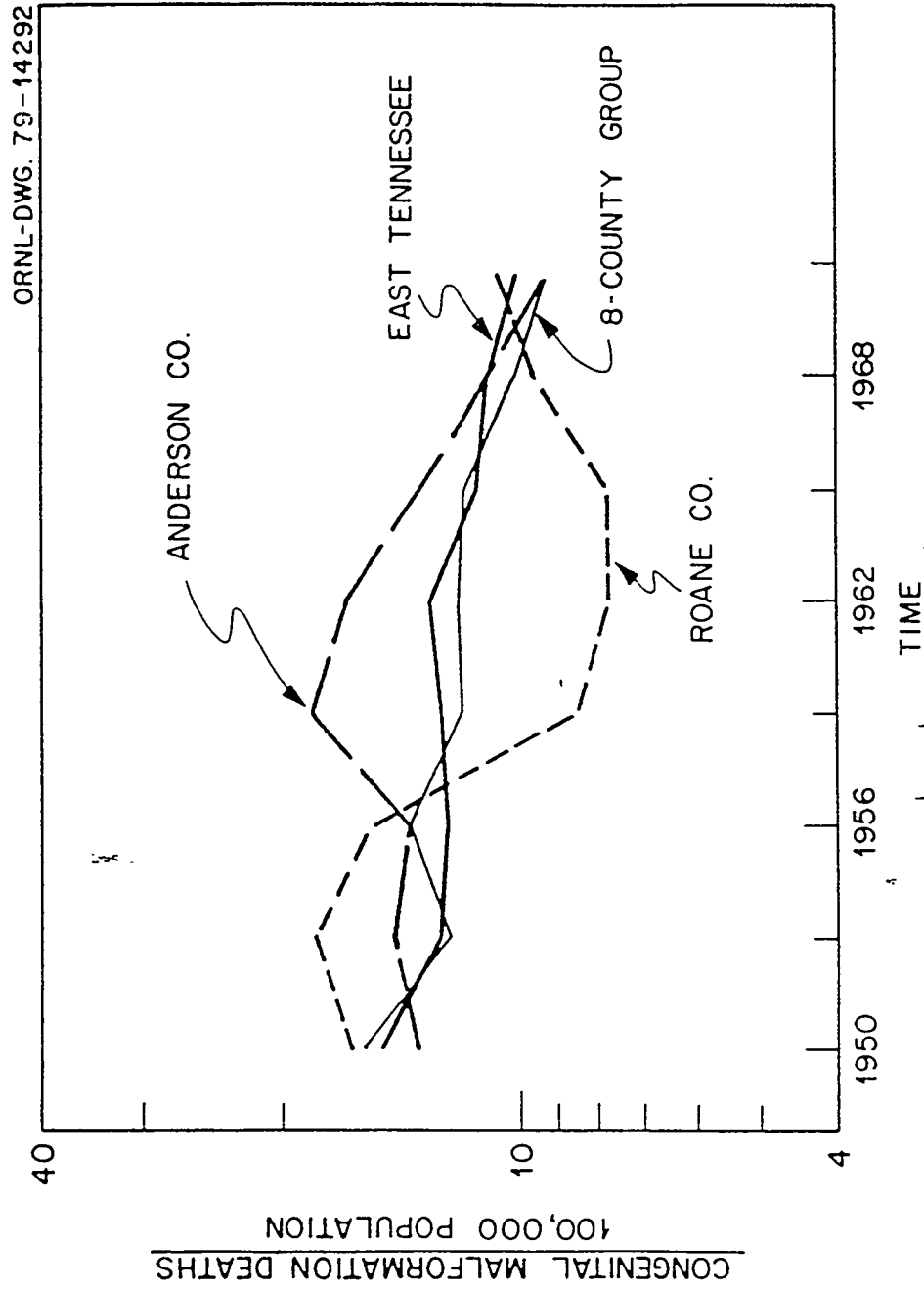
Fig. 6. Congenital malformation rate (year-of-death technique) vs time.

the period 1958-1971. When Anderson County is compared to Blount and Knox County combined (same SEA), there is no significant difference for 1949-1957 and significantly greater than expected for 1958-1971.

For the preceding data, the congenital malformation deaths are compared to the population to obtain rates; this is the conventional technique. Further, they are compiled for the vital statistics publications according to the year of death regardless of age. While the use of this kind of data might be acceptable for studies of a population in equilibrium with cultural and environmental effects, it is questionable for the region surrounding the city of Oak Ridge between 1930 and 1971. During this time, significant changes occurred in both socioeconomic and physical environments. Therefore, in this investigation, congenital malformation deaths are presented in the above-mentioned conventional manner (based on year of death and rates calculated on population numbers) and using a different technique described below.

Based on year of birth

Congenital malformation deaths are also tabulated on the basis of year of birth regardless of age at death. This birth cohort procedure allows changes in serious congenital effects to be associated with time. This is done as insults to a developing fetus may be genetic (inherited) or acquired (environmental), and, depending on the insult, final expression in death may occur over a time span including preimplantation to old age. The initial insult and applied therapeutic procedures will be the controlling factors in the ultimate time of final expression. Using this technique, rates are determined per 1000 live births for each year.

The rates determined are not true rates in that for all years studied, all deaths are either not on our data tapes (for earlier years) or have not yet occurred. Thus, the total number of deaths from a given birth year might not have occurred within the study period. However, this procedure does provide for direct comparison of rates for different population groups and does allow for a "finer tuning" of attempts to correlate changes in health with changes in external conditions.

Table 6 shows the age distribution for the number of deaths attributed
to congenital malformations in the state of Tennessee for 1970. Within the
age bracket of 0 to 1 year, 71% of these deaths occur; however, a
significant contribution to the total occurs for ages significantly
greater than infancy.

Table 6. Age distribution of congenital malformation deaths
for the state of Tennessee — 1970

Age	% of deaths
0-1	71.1
2	2.1
3	1.3
4	1.3
5-9	3.9
10-14	1.8
15-19	2.6
20-24	1.8
25-29	1.6
30-34	1.3
35-44	2.9
45-54	3.4
55-64	2.1
65-74	1.8
75-84	0.3
>85	0.5

The congenital malformation death data based on year of birth is
presented in Tables 7 through 9 with the observed values compared to the
expected values using both the state and East Tennessee as controls; the
spatial orientation of this data is presented in Fig. 7. The entire
data used in the year-of-birth technique is given in Appendix C, and
the congenital rate over time is shown in Fig. 8.

Table 7. Congenital malformation data for 1930 to 1943

(based on year of birth)

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	8	4	4.0*	4	4.0*
Campbell	2	6	2.67	5	1.80
Knox	20	23	0.39	20	0.00
Loudon	1	3	1.33	3	1.33
Morgan	8	2	18.0*	2	18.0*
Roane	3	5	0.80	4	0.25
Scott	2	2	0.00	2	0.00
Union	1	1	0.00	1	0.00

*Observed significantly greater than expected.

$\chi^2_{df=1, \alpha=0.05}$ (two-tail) = 3.84.

Table 8. Congenital malformation data for 1944 to 1957

(based on year of birth)

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	84	94	1.06	85	0.01
Campbell	65	50	4.50*	45	8.89*
Knox	251	271	1.48	244	0.20
Loudon	29	32	0.28	28	0.04
Morgan	11	20	4.05*	18	2.72
Roane	51	49	0.08	44	1.11
Scott	21	26	0.96	23	0.17
Union	6	10	1.60	9	1.00
City					
Oak Ridge	31	31	0.00	28	0.32

*Observed significantly greater than expected.

$\chi^2_{df=1, \alpha=0.05}$ (two-tail) = 3.84.

Table 9. Congenital malformation data for 1958 to 1971
(based on year of birth)

County	Observed	Expected using state rates	χ^2	Expected using East Tennessee rates	χ^2
Anderson	91	79	1.82	76	2.96
Campbell	48	40	1.60	39	2.08
Knox	290	313	1.69	300	0.33
Loudon	32	30	0.13	29	0.41
Morgan	15	18	0.50	17	0.24
Roane	34	50	5.12[†]	48	4.08[†]
Scott	28	25	0.36	24	0.67
Union	11	12	0.08	11	0.00
City		—			
Oak Ridge	39	33	1.09	31	1.64

[*]Observed significantly greater than expected.

[†]Observed significantly less than expected.

$\chi^2_{df=1, \ \alpha=0.05}$ (two-tail) = 3.84.

ORNL—DWG 79-14852R

CHI-SQUARED COMPARISONS USING
STATE EXPECTED RATES

CHI-SQUARED COMPARISONS USING
EAST-TENNESSEE EXPECTED RATES

1930—1943

1930—1943

1944—1957

1944—1957

1958—1971

1958—1971
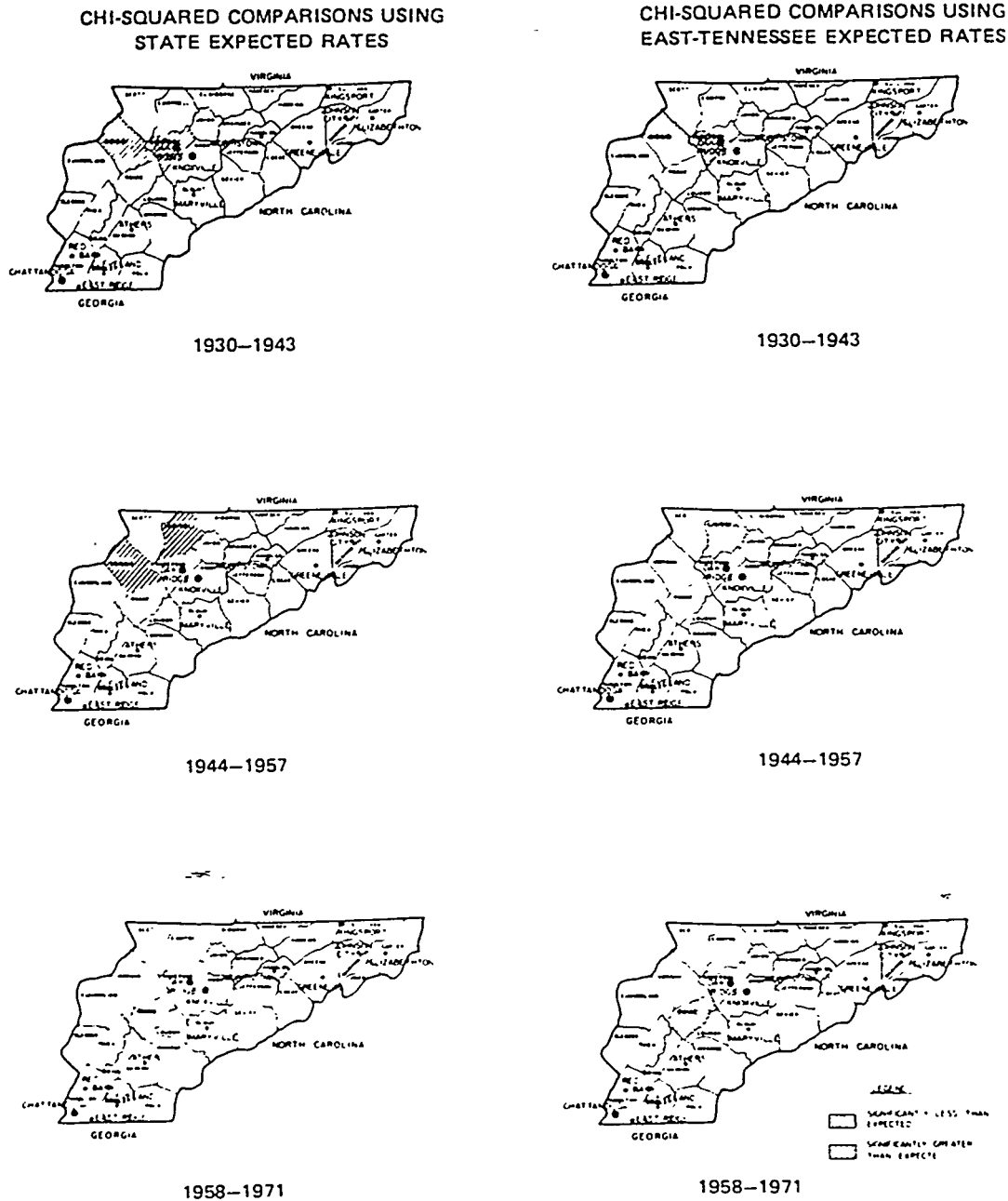
Fig. 7. Spatial orientation of congenital malformation data (year-of-birth technique).
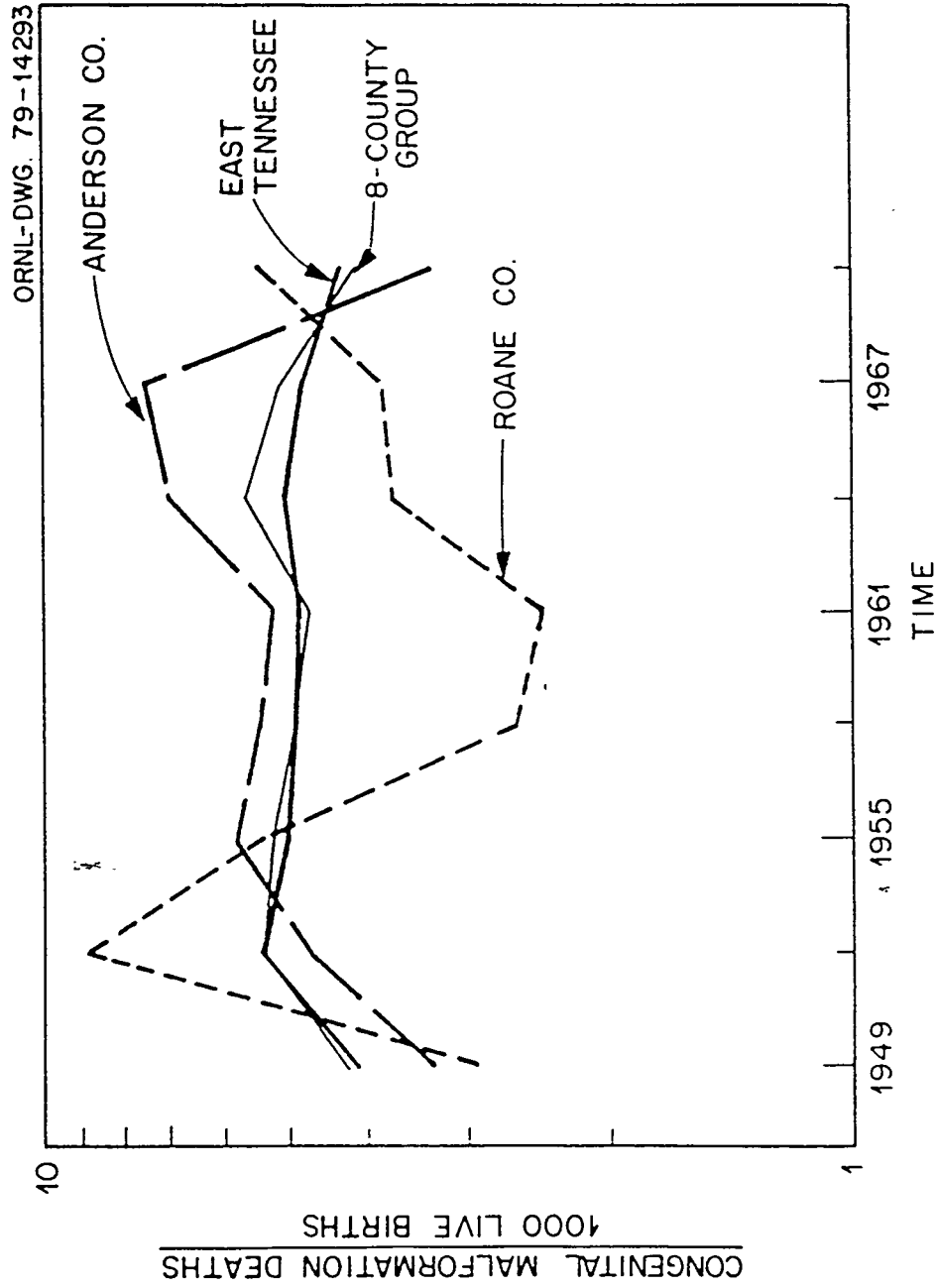
Fig. 8. Congenital malformation rate (year-of-birth technique) vs time.

DISCUSSION

In any retrospective study involving a population response, one must choose a suitable span of time over which to aggregate events. The basic data used in this study are deaths per year in a city or a county where the numbers range from no events to several hundred, with many years having less than 10 events per county. As a result of this situation, the observable "significant difference" was found to vary considerably depending on the time interval over which events were aggregated. For example, in the stillbirth data using state expected rates, for comparison with the eight county area, if the time interval chosen is 1933 to 1946, only Loudon county is calculated to have significantly more deaths than the state as a whole. Using 1930 through 1943, Loudon county is again calculated to have significantly more deaths with Roane County calculated to be significantly less. For 1955 to 1968, Campbell, Scott, and Union counties are computed to be significantly worse than the state; however, when using the time period 1957 to 1971, Campbell, Knox, Loudon, Roane, Scott, and Union are all computed to be significantly worse.

Changes in significant differences also occurred in the congenital malformation data when the time period that was studied was changed slightly. Thus, the "significance" or "nonsignificance" of the counties with a small number of events and large year-to-year variation should be viewed with a measure of caution. Of the philosophies leading to the selection of time intervals, the one chosen (as described in the Introduction) appears to be the most relevant for the present study; however, the basic data are presented in the appendices for alternate analyses.

In comparing the counties, no consistent correlation was found between the two indicators for counties with observations higher or lower than expected. Further, no significant correlation using single correlation techniques, was found between the two chosen indicators and average income, education, or other typical socioeconomic correlates.[5]

SUMMARY

The stillbirth and congenital malformation death data have been presented for counties surrounding the Oak Ridge nuclear facilities; the variables analyzed were chosen as they are taken to be sensitive indicators of the effects from radiation exposure. Oak Ridge, which is the closest city to the nuclear facilities, had significantly fewer stillbirths and no difference in congenital malformations as compared with the state or East Tennessee. Further, no time trend was observed in the 8-county data which could be associated with the higher levels of radioactive releases during the 1944-1957 period followed by a period of lesser releases in the 1958-1971 period. A clustering of stillbirths was found for the last time period; however, since the present study is primarily descriptive, no detailed examination of the potential causes has been made. The significance of choosing different time intervals for analyses was discussed. The choice of using either East Tennessee or the state as a control group also was found to change the significance of the chi-square test. Finally, no significant relationship was found between the occurrence of stillbirths and congenital malformation deaths, and no relationship was found between the stillbirth and congenital malformation data and average income, education, or other socioeconomic correlates.

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APPENDIX A

STILLBIRTH DATA

State of Tennessee

(Source: Annual Bulletins of Vital Statistics)

	STATE		EAST TENNESSEE	
Year	Live births	Stillbirths	Live births	Stillbirths
1930	38,906	1,582	12,423	546
1931	38,694	1,510	12,557	530
1932	38,782	1,459	12,893	497
1933	36,926	1,388	12,222	505
1934	38,415	1,401	13,464	535
1935	38,740	1,374	13,503	517
1936	36,770	1,240	13,155	454
1937	37,767	1,266	13,374	516
1938	39,704	1,215	14,172	459
1939	39,296	1,130	14,282	443
1940	40,378	1,040	15,161	405
1941	43,484	978	16,111	319
1942	47,057	962	17,635	370
1943	50,630	1,042	18,528	370
1944	48,243	934	17,419	374
1945	44,811	900	16,434	376
1946	53,885	1,076	19,587	433
1947	60,966	1,100	22,215	443
1948	56,776	1,015	20,344	402
1949	56,922	1,046	20,149	353
1950	55,137	936	18,810	367
1951	57,187	961	19,557	353
1952	55,539	943	18,846	337
1953	55,560	853	18,908	330
1954	56,921	881	19,478	326
1955	56,274	846	19,697	319
1956	56,126	882	19,395	337
1957	55,877	802	19,096	328
1958	55,553	821	18,588	270
1959	55,205	756	18,565	263
1960	54,384	782	18,109	267
1961	54,685	771	18,308	292
1962	54,097	797	18,029	274
1963	53,344	750	17,537	271
1964	53,851	747	17,978	264
1965	48,912	678	16,217	261
1966	46,610	699	16,038	271
1967	45,968	620	16,007	249
1968	45,985	657	15,837	240
1969	47,963	593	16,402	240
1970	49,644	662	17,193	259
1971	48,768	592	16,962	207

| | ANDERSON COUNTY | | CAMPBELL COUNTY | |
Year	Live births	Stillbirths	Live births	Stillbirths
1930	400	15	548	28
1931	398	13	653	23
1932	482	22	634	7
1933	472	21	558	16
1934	559	32	693	17
1935	689	26	757	32
1936	603	22	700	22
1937	547	18	665	31
1938	541	19	702	31
1939	530	8	739	25
1940	493	15	756	14
1941	571	16	756	16
1942	601	2	851	17
1943	697	14	960	13
1944	878	15	991	14
1945	1569	23	924	18
1946	1997	24	1043	25
1947	2014	43	1047	23
1948	1817	40	1030	22
1949	1735	23	1010	21
1950	1644	22	905	30
1951	1737	30	853	31
1952	1718	18	821	29
1953	1683	24	763	9
1954	1832	20	824	21
1955	1760	25	826	21
1956	1576	25	733	16
1957	1513	20	730	17
1958	1521	17	640	7
1959	1380	14	655	10
1960	1390	19	588	12
1961	1357	22	699	15
1962	1278	13	590	9
1963	1213	19	615	6
1964	1220	14	604	15
1965	1009	10	523	14
1966	948	12	522	8
1967	889	11	527	10
1968	880	9	531	10
1969	874	19	490	9
1970	907	14	457	6
1971	922	16	584	13

	KNOX COUNTY		LOUDON COUNTY	
Year	Live births	Stillbirths	Live births	Stillbirths
1930	2890	119	416	15
1931	2593	107	410	20
1932	2666	108	448	18
1933	2524	98	438	19
1934	2678	79	453	21
1935	2589	85	438	24
1936	2680	90	396	24
1937	2725	87	416	18
1938	2766	71	386	22
1939	2780	78	403	12
1940	3119	80	407	12
1941	3443	70	410	9
1942	3724	79	519	11
1943	3964	78	552	14
1944	3959	76	524	7
1945	3845	87	538	13
1946	4746	97	657	9
1947	5086	109	715	12
1948	4793	116	593	7
1949	4758	91	599	18
1950	4545	93	507	10
1951	4922	98	544	11
1952	4974	76	481	7
1953	5056	83	565	10
1954	5370	78	565	11
1955	5375	79	545	7
1956	5244	73	520	11
1957	5061	81	538	9
1958	4954	68	523	13
1959	5006	78	518	1
1960	5081	68	463	4
1961	4926	72	484	10
1962	4862	73	474	11
1963	4828	70	450	9
1964	4819	73	443	10
1965	4128	74	441	6
1966	3964	76	370	4
1967	3928	52	373	5
1968	3759	59	362	10
1969	4129	63	395	6
1970	4131	55	356	10
1971	4080	50	370	8

	MORGAN COUNTY		ROANE COUNTY	
Year	Live births	Stillbirths	Live births	Stillbirths
1930	301	20	595	29
1931	322	10	561	21
1932	311	7	563	19
1933	287	5	523	20
1934	322	14	575	19
1935	296	11	565	11
1936	274	9	589	11
1937	307	12	588	12
1938	308	10	574	24
1939	314	9	555	13
1940	301	6	620	15
1941	296	6	688	10
1942	309	7	726	9
1943	341	2	685	14
1944	373	3	789	17
1945	372	7	826	23
1946	419	10	834	21
1947	423	11	879	23
1948	428	11	845	16
1949	425	3	808	25
1950	362	8	790	16
1951	353	10	778	18
1952	348	4	838	21
1953	298	8	896	14
1954	328	9	1079	15
1955	324	2	968	9
1956	307	5	928	11
1957	298	3	894	17
1958	290	9	882	15
1959	313	6	870	9
1960	272	1	843	23
1961	275	7	823	13
1962	312	3	813	13
1963	298	6	774	16
1964	289	3	756	15
1965	236	5	635	3
1966	217	5	630	9
1967	224	5	607	14
1968	200	2	597	13
1969	211	4	608	13
1970	232	1	580	11
1971	238	0	658	12

	SCOTT COUNTY		UNION COUNTY	
Year	Live births	Stillbirths	Live births	Stillbirths
1930	263	18	189	5
1931	210	7	261	11
1932	221	9	272	10
1933	194	10	268	7
1934	216	12	238	7
1935	240	8	196	7
1936	230	10	136	5
1937	256	13	137	3
1938	262	6	121	4
1939	198	10	112	3
1940	260	7	111	1
1941	324	9	155	3
1942	400	1	132	3
1943	423	4	139	5
1944	431	4	169	7
1945	415	3	173	1
1946	442	6	211	3
1947	527	16	188	7
1948	532	13	192	7
1949	588	10	202	3
1950	497	13	154	2
1951	473	12	160	1
1952	452	12	163	4
1953	431	5	150	2
1954	431	11	142	2
1955	417	5	172	4
1956	414	9	178	2
1957	381	8	177	1
1958	418	8	182	2
1959	425	9	183	3
1960	378	6	152	8
1961	392	3	189	7
1962	412	10	157	0
1963	408	4	175	4
1964	386	6	158	3
1965	332	4	164	5
1966	332	9	176	4
1967	298	9	177	2
1968	334	7	131	2
1969	311	7	152	2
1970	305	6	165	0
1971	298	6	157	2

	BLOUNT & KNOX COUNTIES		OAK RIDGE	
Year	Live births	Stillbirths	Live births	Stillbirths
1930	3753	165		
1931	3307	140		
1932	3413	133		
1933	3198	126		
1934	3446	110		
1935	3360	112		
1936	3441	111		
1937	3578	126		
1938	3742	102		
1939	3765	111		
1940	4133	110		
1941	4586	96		
1942	5030	95		
1943	5325	103		
1944	5201	102		
1945	4996	117		
1946	6079	126		
1947	6615	145		
1948	6163	142		
1949	6108	112	976	10
1950	5807	118	822	11
1951	6301	115	922	18
1952	6267	94	946	10
1953	6447	100	867	6
1954	6819	95	948	3
1955	6767	103	891	8.
1956	6653	95	766	6
1957	6471	97	659	4
1958	6126	77	629	9
1959	6143	93	564	2
1960	6188	86	558	6
1961	6072	100	568	8
1962	5958	84	533	4
1963	5943	86	513	5
1964	5898	88	509	4
1965	5114	90	422	1
1966	4974	98	390	5
1967	4916	61	356	1
1968	4697	69	362	4
1969	5118	75	376	7
1970	5171	73	359	6
1971	5100	60	372	3

APPENDIX B

CONGENITAL MALFORMATION DATA

(Year-of-Death Technique)

(Source: State of Tennessee Annual Bulletins of Vital Statistics)

	STATE		EAST TENNESSEE	
Year	Population	C.M.s	Population	C.M.s
1949	2,335,394	356	776,278	116
1950	2,371,574	325	783,288	111
1951	2,412,133	338	798,739	126
1952	2,443,422	338	791,474	92
1953	2,474,721	350	818,953	106
1954	2,506,015	347	829,060	111
1955	2,537,305	338	839,164	93
1956	2,568,599	352	849,271	118
1957	2,599,891	314	859,378	103
1958	2,631,187	343	869,484	100
1959[a]	2,598,466	365	856,171	113
1960	2,565,781	375	842,865	107
1961	2,565,781	358	842,865	127
1962	2,613,707	374	856,345	99
1963	2,655,386	348	869,779	109
1964	2,730,890	363	893,043	119
1965	2,779,420	326	886,625	94
1966	2,809,507	315	897,438	91
1967	2,797,259	323	893,946	112
1968	2,883,836	300	924,245	97
1969	2,896,862	282	928,181	93
1970[a]	2,902,421	304	937,304	97
1971	2,908,023	29.7	946,440	92

[a]Population numbers are interpolated values.

	ANDERSON COUNTY		CAMPBELL COUNTY	
Year	Population	C.M.s	Population	C.M.s
1949	54,997	10	33,556	11
1950	57,518	5	33,904	11
1951	57,594	8	34,363	11
1952	57,594	5	34,695	6
1953	57,594	12	35,028	11
1954	57,594	8	35,360	4
1955	57,594	11	35,692	5
1956	57,594	5	36,024	3
1957	57,594	8	36,356	2
1958	57,594	10	36,689	6
1959[a]	57,784	12	32,181	4
1960	57,973	10	27,672	5
1961	57,973	15	27,672	5
1962	57,915	4	27,672	7
1963	58,537	10	27,672	3
1964	59,578	7	28,359	2
1965	59,048	11	27,959	3
1966	60,969	6	28,089	6
1967	59,659	8	27,761	3
1968	60,062	7	27,107	5
1969	60,281	5	27,216	5
1970[a]	57,999	7	26,746	2
1971	58,977	4	26,276	3

[a] Population numbers are interpolated values.

	KNOX COUNTY		LOUDON COUNTY	
Year	Population	C.M.s	Population	C.M.s
1949	198,385	37	22,241	2
1950	201,779	19	22,568	3
1951	206,661	31	23,076	4
1952	210,785	18	23,418	2
1953	214,910	22	23,760	4
1954	219,035	24	24,102	2
1955	223,159	35	24,444	6
1956	227,284	27	24,786	2
1957	231,408	41	25,128	4
1958	235,533	26	25,470	2
1959[a]	231,568	22	24,390	4
1960	227,603	17	23,310	8
1961	227,603	23	23,310	1
1962	232,900	23	23,401	2
1963	232,877	37	23,704	3
1964	244,622	37	24,177	0
1965	243,177	21	23,871	3
1966	246,676	28	24,435	1
1967	244,232	19	23,496	2
1968	244,061	27	24,212	1
1969	245,135	23	24,318	2
1970[a]	250,813	25	24,237	5
1971	256,491	14	24,155	3

[a]Population numbers are interpolated values.

	MORGAN COUNTY		ROANE COUNTY	
Year	Population	C.M.s	Population	C.M.s
1949	15,277	1	29,852	4
1950	15,321	2	30,190	3
1951	15,454	5	30,608	8
1952	15,509	0	30,983	4
1953	15,565	1	31,358	8
1954	15,620	2	31,734	5
1955	15,676	0	32,109	10
1956	15,732	1	32,484	2
1957	15,787	2	32,859	3
1958	15,843	3	33,234	5
1959[a]	14,920	3	35,373	2
1960	13,996	3	37,512	2
1961	13,996	2	37,512	3
1962	13,996	0	39,074	3
1963	13,996	0	40,211	3
1964	14,344	4	41,655	4
1965	14,359	1	37,634	3
1966	14,117	0	37,612	2
1967	13,837	1	37,861	2
1968	14,153	2	38,335	4
1969	14,209	1	38,504	5
1970[a]	13,916	2	38,175	3
1971	13,622	3	37,846	5

[a]Population numbers are interpolated values.

	SCOTT COUNTY		UNION COUNTY	
Year	Population	C.M.s	Population	C.M.s
1949	17,261	0	8,690	0
1950	17,396	2	8,668	2
1951	17,526	3	8,669	2
1952	17,665	2	8,669	0
1953	17,804	4	8,669	1
1954	17,943	4	8,669	0
1955	18,082	2	8,669	2
1956	18,220	1	8,669	0
1957	18,359	4	8,669	0
1958	18,498	1	8,669	1
1959[a]	16,954	1	8,593	2
1960	15,410	2	8,496	0
1961	15,410	3	8,496	0
1962	15,410	1	8,457	0
1963	15,410	3	8,440	0
1964	15,793	5	8,631	0
1965	16,125	1	8,848	1
1966	16,268	5	9,221	3
1967	15,818	1	9,163	1
1968	16,179	6	9,737	0
1969	16,243	0	9,776	2
1970[a]	15,622	1	9,499	1
1971	15,000	4	9,221	0

[a]Population numbers are interpolated values.

	BLOUNT & KNOX COUNTIES		OAK RIDGE	
Year	Population	C.M.s	Population	C.M.s
1949	249,408	51	31,199	4
1950	254,051	25	28,864	1
1951	260,091	45	29,027	6
1952	265,497	21	29,027	1
1953	270,904	28	29,027	7
1954	276,311	34	29,027	2
1955	281,717	40	29,027	5
1956	287,124	39	29,027	3
1957	292,530	54	29,027	3
1958	297,937	28	29,027	6
1959[a]	290,136	32	27,405	6
1960	282,335	22	25,782	5
1961	282,335	34	25,782	5
1962	288,150	29	25,782	1
1963	293,976	44	25,782	4
1964	301,979	48	28,166	1
1965	299,669	29	28,166	3
1966	305,055	36	28,340	3
1967	302,767	24	29,473	3
1968	303,539	35	30,244	4
1969	304,871	26	30,927	1
1970[a]	311,789	34	28,765	4
1971	318,706	18	26,603	1

[a]Population numbers are interpolated values.

APPENDIX C

CONGENITAL MALFORMATION DATA

(Year-of-Birth Technique)

(Source: State of Tennessee, Department of Health)

Year	STATE C.M.s	EAST TENNESSEE C.M.s	ANDERSON COUNTY C.M.s
1930	18	6	2
1931	18	8	0
1932	21	6	2
1933	15	3	0
1934	30	6	0
1935	18	5	0
1936	26	9	2
1937	21	4	0
1938	24	8	1
1939	25	9	0
1940	22	9	0
1941	18	6	0
1942	25	11	0
1943	37	7	1
1944	38	8	0
1945	29	11	1
1946	42	17	0
1947	45	12	5
1948	62	15	0
1949	354	112	12
1950	338	114	5
1951	321	123	9
1952	307	84	5
1953	321	104	10
1954	326	98	12
1955	321	92	11
1956	301	103	7
1957	281	88	7
1958	295	80	10
1959	312	108	7
1960	316	92	8
1961	263	95	9
1962	284	76	4
1963	276	88	8
1964	290	96	7
1965	247	73	9
1966	218	68	6
1967	240	98	9
1968	205	66	5
1969	210	76	3
1970	226	70	2
1971	214	70	4

Year	CAMPBELL COUNTY C.M.s	KNOX COUNTY C.M.s	LOUDON COUNTY C.M.s
1930	0	2	0
1931	0	2	0
1932	0	1	0
1933	0	0	0
1934	0	0	0
1935	0	0	0
1936	0	1	0
1937	1	0	0
1938	0	0	0
1939	0	3	0
1940	0	1	1
1941	1	3	0
1942	0	1	0
1943	0	6	0
1944	0	4	0
1945	0	0	1
1946	0	2	0
1947	0	5	0
1948	2	6	1
1949	12	37	2
1950	11	18	4
1951	10	25	4
1952	6	18	4
1953	11	20	3
1954	4	24	1
1955	4	36	5
1956	3	22	2
1957	2	34	2
1958	6	25	3
1959	5	17	2
1960	5	17	9
1961	5	20	1
1962	3	25	3
1963	3	31	2
1964	2	34	0
1965	3	20	3
1966	5	17	0
1967	1	16	1
1968	3	21	1
1969	3	20	2
1970	1	18	3
1971	3	9	2

Year	MORGAN COUNTY C.M.s	ROANE COUNTY C.M.s	SCOTT COUNTY C.M.s
1930	0	0	0
1931	1	0	0
1932	0	0	0
1933	0	0	0
1934	1	0	0
1935	1	1	0
1936	0	1	0
1937	1	0	1
1938	0	0	0
1939	1	1	0
1940	0	0	0
1941	1	0	0
1942	0	0	0
1943	2	0	1
1944	0	1	1
1945	0	0	0
1946	0	1	0
1947	0	0	0
1948	0	2	0
1949	1	2	2
1950	2	3	1
1951	3	8	2
1952	0	6	3
1953	1	8	2
1954	1	5	4
1955	2	9	3
1956	0	2	0
1957	1	4	3
1958	1	1	1
1959	2	2	1
1960	2	2	2
1961	2	2	4
1962	1	2	2
1963	0	3	1
1964	3	3	3
1965	0	2	0
1966	1	2	3
1967	1	1	1
1968	1	4	5
1969	0	2	0
1970	0	3	2
1971	1	5	3

Year	UNION COUNTY C.M.s	BLOUNT & KNOX COUNTIES C.M.s	OAK RIDGE C.M.s
1930	0	2	0
1931	0	3	0
1932	0	1	0
1933	0	0	0
1934	0	0	0
1935	0	0	0
1936	1	1	0
1937	0	0	0
1938	0	0	0
1939	0	4	0
1940	0	2	0
1941	0	4	0
1942	0	2	0
1943	0	7	0
1944	0	4	0
1945	0	1	1
1946	0	3	0
1947	0	8	3
1948	0	7	0
1949	0	48	1
1950	2	24	1
1951	1	40	6
1952	0	20	1
1953	1	27	4
1954	1	30	4
1955	1	42	4
1956	0	34	4
1957	0	44	2
1958	1	29	5
1959	2	25	4
1960	0	21	4
1961	0	32	3
1962	0	28	1
1963	0	36	4
1964	0	45	1
1965	2	24	2
1966	3	22	3
1967	1	21	5
1968	0	26	4
1969	1	23	0
1970	1	24	2
1971	0	10	1

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